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AN ANALYSIS AND COMPARISON OF ALTERNATIVE TECHNIQUES FOR INCORPORATING PREFERENTIAL SUPPORT FOR SELECTED USERS INTO THE AIR FORCE RECOVERABLE CENTRAL LEVELING SYSTEM

Roy B. Gaskill, Captain, USAF
Douglas E. Keller, GS-12

LSSR 13-81 ✓

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The Air Force Recoverable Central Leveling System (DSD D028) is the first phase of a comprehensive plan for stock-level computation, distribution, and redistribution of selected recoverable supply items. The D028 system is intended to allocate available assets between users so that the total number of expected user backorders is held to a minimum. Current supply directives provide increased supply support for certain Air Staff designated users through the mechanism of the "C-Factor." The current D028 algorithm design includes logic to provide increased support to these selected users. The objective of this study was to explore alternative approaches to preferential support within the D028 system. A data base was assembled consisting of all supply items in D028 which are authorized preferential support. The effects of current D028 support procedures are assessed in terms of the enhancement of fill rates for preferred users and the degradation of fill rates for nonpreferred users. In addition, three alternative procedures which could be used in D028 to provide preferential support are developed, and their effects on item/user fill rates are determined. Results indicated significant differences across all alternatives. Managerial decisions in determining the alternative to use were discussed.

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AN ANALYSIS AND COMPARISON OF ALTERNATIVE TECHNIQUES FOR INCORPORATING PREFERENTIAL SUPPORT FOR SELECTED USERS INTO THE AIR FORCE RECOVERABLE CENTRAL LEVELING SYSTEM

A Thesis

Presented to the Faculty of the School of Systems and Logistics

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In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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June 1981

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This thesis, written by

Captain Roy B. Gaskill

and

Mr. Douglas E. Keller

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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CHAPTER I

INTRODUCTION

Impetus for Research

The Logistics Long-Range Planning Guide (LLPG) (7), identifies four broad logistics objectives developed to support the Air Force through the year 2000. The fourth objective is to "*effectively manage or influence the management of scarce logistics resources to maintain Air Force combat capability [italics mine]* [7:1]." Figure II in the LLPG reflects the percentage of the total Air Force military personnel, enlisted force, and the Air Force budget which were required to perform the logistics mission in 1980; 43, 50, and 25 percent, respectively. Assuming these past percentages reflect the future, the effective management of scarce logistics resources is essential for our national security. Two of the eleven "major logistics issues" identified in the LLPG are major areas of concern to this research effort: Logistics Planning and Asset Management.

Within the logistics planning area,

> . . . greater emphasis must be placed on assessing and identifying logistics support capability in order to appraise realistically what can or cannot be accomplished with available assets [7:2].

The LLPG (7:3) points out that recent Air Force budgets have

not included adequate funding for spares to support a wartime effort.

The existence of this situation is attributed (7:3), in part, to be ". . . a poorly articulated logistics position during the POM preparation cycle," and ". . . an inadequate requirements computation process. . . ." The planning function must identify the items essential to the Air Force mission and the requirements computation processes must determine the correct quantity of these items necessary to permit successful completion of this mission.

With today's limited funds, stock shortages have become the rule rather than the exception. Effective management of Air Force resources is essential.

> Recognizing that there will probably be a limited number of spares to work with, it is essential the logistics manager know the requirement, condition, availability, and location of these scarce assets at all times [7:3].

Logistics managers must be equipped with the proper tools for keeping pace with the dynamic nature of world politics. Logistics information systems are one of these tools; these systems must be flexible and reliable. To ensure these systems meet the challenge of potential problems becoming real problems, peacetime efforts are required to prove the flexibility and the reliability of these systems. Another logistics management tool is a responsive and reliable transportation system. Resources are of little value, unless we have the capability to deliver the resources to

needy users in a timely manner. "Recent studies indicate that there are direct sortie production payoffs if assured transportation exists to rapidly move lateral resupply items within the theater [7:4]." Logistics Planning and Asset Management are part of the Logistics Process; a process that

> . . . gives resources utility by causing them to be: The right thing (. . . right quantity and quality). In the right place (where it's needed). At the right time (when it's needed) [13:3-1,3-2].

Research Direction

Headquarters, Air Force Logistics Command (HQ AFLC) is conducting an on-line service test of the Air Force Recoverable Central Leveling System (DSD D028) at Kelly AFB, Texas. The D028 system is intended as one of the logistics manager's tools for providing the right thing, in the right place, and at the right time. The D028 system computes Air Force users' (AF bases) stock levels. One portion of the D028 system's algorithm is designed to provide increased asset support (preferential support) to selected Air Force users. This increased asset capability is required by HQ USAF (8:3) in support of possible contingencies. An investigation into the D028 system's method for providing increased asset support to selected users is provided in this research.

Background

Current System

Currently, Air Force bases compute stock level requirements on an item-by-item basis. These stock levels are based upon usage data and modified by known future needs (mission change data), when appropriate. Part of the requirement is designed to avoid normal stock outages during resupply time. An additional part of this requirement, safety level stock, is intended to cover variations in usage during the resupply time. HQ USAF has authorized selected Air Force bases to increase their safety level stock by a multiple of two. This increased support is intended to provide an improved asset position to support possible contingencies. Next, the bases requisition items required to satisfy any unsupported requirements, that is, if assets in stock are less than the computed requirement. Requisitions are transmitted to the appropriate Inventory Control Point (ICP) to be filled or placed on backorder, depending upon item availability. In this process, each base computes and requisitions its stock levels independently and without regard to total system needs or asset availability.

Yet, system requirements are computed in the Recoverable Consumption Item Requirements System Variable Safety Level (DSD D041A) using a marginal analysis process.

> Marginal analysis is a mathematical technique for determining the return gained for each additional unit of investment. In this case, the return is in terms of the reduction in backorders (or the improvement in fill rate) to be expected for each additional unit of stock [1:7].

Because the centralized computation of total requirements (1) has been divorced from the requirements computation process at the using bases, the sum of the user computed requirements may exceed total available assets. As a result, the bases will consistently requisition assets which cannot be delivered. On the other hand, total available assets provided by D041A may exceed the sum of the user computed requirements. In this situation, assets which were procured on a cost-effective basis by marginal analysis to provide additional protection stay on the shelf at an inventory control point. These assets stay at the control point because the base does not have a computed requirement for the incremented quantity.

This combination of two requirement philosophies, system optimizing and independent user, has been used in the Air Force for several years. Due to a growing item inventory, budget constraints, increasingly sophisticated weapon systems, and more complexed planning strategies, the need exists to improve the current method of determining user requirements, while aligning the requirements and the distribution processes.

Proposed System or D028 System

The D028 system is the first phase of a comprehensive plan for a stock level computation, distribution, and redistribution of selected recoverable items. This system will operate at each of the Air Logistics Centers (ALCs). The D028 system computes users' levels based upon usage data and negotiated levels in such a manner as to minimize system backorders while allocating all available assets as provided by D041A. The system has incorporated HQ USAF's requirement to provide increased asset support, preferential support, to selected Air Force users during the allocation process. While improving support to selected users, other users' support will be degraded.

Problem Statement

Preferential support is a modification to the optimizing technique, either through restructuring the criterion or through constraints in the problem formulation. There are many alternatives possible to accomplish this modification. Any imposition of preference will result in a distribution problem. Given a fixed number of assets to be distributed, the enhancement of item availability for some users will degrade the item availability to others. What is not currently well understood is the degree of differential support (enhancement/degradation) which is likely to occur under:

1. The current D028 procedures.

2. A number of alternative procedures.

Research Objective

The objective of this study is to perform an empirical test and comparison of alternative procedures to determine their probable effect on user support, so as to provide Air Force management with a sound basis to decide on a procedure which will provide a desirable level of enhanced support to preferred users, without allowing an unacceptable degradation of support to non-preferred users.

CHAPTER II

LITERATURE REVIEW

Overview

The review of applicable literature is concentrated in the following areas: current procedures for the computation of Air Force base levels, the Multi-Echelon Technique for Recoverable Item Control (METRIC), the Air Force uses of METRIC, the Air Force Recoverable Central Leveling System (DSD D028), and the requirement for preferential support for selected Air Force bases.

Current USAF Procedures for Establishing Base Stockage Levels

The current procedures require the computation of Air Force base stock levels be based, in part, upon past demands, on an item-by-item basis (15:p.11-3). These demands are expressed as the sum of three quantities:

1. A repair cycle quantity is ". . . the number of units that must be stocked to meet demands during the repair cycle [15:p.11-3]."

2. An order and shipping time quantity is ". . . the quantity required to be on hand to meet demands during the period represented by the order and shipping time [15:p.11-3]."

3. A safety level quantity is

> . . . those assets required to be on hand to permit continuous operation in the event of minor interruption of normal or unpredictable increases in demands [15:p.11-3].

In order to better describe these three quantities, additional elements require definition:

1. Daily Demand Rate (DDR) is equal to the total recurring demands divided by the number of days in which demands occurred (15:p.11-3).

2. "Number of units shipped off base for repair (NRTS) [14:p.11-4]."

3. "Number of units repaired on base, repaired this station (RTS) [14:p.11-4]."

4. Base repair rate is equal to the quantity repaired this station (RTS) divided by the sum of RTS, NRTS, and condemned quantities (14:p.11-6).

5. Order and Shipping Time (O&ST) is the time required to order an item plus the time required for a serviceable item to be shipped from the depot (15:p.11-3).

6. Base Repair Cycle Time (BRCT) is the time normally required at the base level for an item to pass through the various unserviceable stages, from the time of removal until it is restored to a serviceable condition (14:p.11-11).

The three quantities comprising the demand level can now be defined in more precise terms:

1. Repair Cycle Quantity = DDR · Base Repair Rate · BRCT (14:p.11-6).

2. O&ST Quantity = DDR (1-Base Repair Rate) · O&ST (14:p.11-6).

3. Safety Level = $C\sqrt{3(\text{Repair Cycle Qty} + \text{O\&ST Qty})}$

where:

> C equals the number of standard deviations from the mean. C equals 1 in this formula except for units which are authorized by HQ USAF/LEYP to use the standard deviation factor 2 for key items to provide a means for positioning assets forward in the hands of the user [14:p. 11-6].

In the Safety Level formula a new term has been introduced, C or C-factor. Further explanation of this term is necessary.

The words, ". . . to provide a means for positioning assets forward in the hands of the user," were referred to in Chapter I as, ". . . increased asset support (preferential). . . ." If the probability distribution of demands is assumed to be normal or approximately normal, with a variance to mean ratio of 3 to 1, then it can be shown that a C value of 1 will result in approximately an 84 percent support effectiveness or performance, when defined in terms of a fill rate. In a similar manner, it can be shown that a C value of 2 will result in approximately a 97 percent fill rate. Clearly, a user authorized a C value of 2 receives "preferential support" for a particular item in comparison to what the user would receive if only authorized a C value of 1.

METRIC

In early 1962, HQ USAF requested The RAND Corporation undertake a study directed toward evaluation of a base

stockage policy for recoverable spare parts. As a result of this study, the "Base Stockage Model" was developed. Several years and many studies later the "Multi-Echelon Technique for Recoverable Item Control (METRIC)" was developed.

> METRIC is a mathematical model translated into a computer program, capable of determining base and stock levels for a group of recoverable items; its governing purpose is to optimize system performance for specified levels of system investment [11:2].

System performance is expressed in terms of system backorders. METRIC can be used in two ways in determining levels for these particular items.

First, the model can be used in the requirements computation process, optimizing investment dollars across all items to achieve the lowest number of system backorders. Second, the model can be used to optimally distribute assets between bases and depot stock level in order to minimize the expected number of system base backorders, given available assets. This research effort is mainly interested in METRIC with regard to its use in the distribution process.

The METRIC algorithm uses the numerical estimate of expected system backorders as a measure of effectiveness, that is, to determine where the next unit will be allocated to achieve the maximum benefit. Two types of backorders exist, base and depot. A depot backorder is only of interest in how it affects base backorders. A base backorder can be defined as an unsatisfied item demand occurring at the base level at a random point in time. This is expressed mathematically by Sherbrooke (11:14) as:

$$B(s) = \sum_{x=s+1}^{\infty} (x-s) \cdot p(x \mid \lambda T) .$$

In this formula s is the stock level, with demands expressed by a compound Poisson distribution with a mean arrival rate of λ. The resupply time is an arbitrary distribution $\psi(t)$ with a mean of T (11:13).

Sherbrooke (11:13) defines the expected number of demands placed upon the depot (EDD) in terms of the mean demand rate at the base (λ_j) and the probability that the item will be returned to the depot for repair.

$$EDD = \sum_{j=1}^{n} \lambda_j \cdot (1-r_j)$$

where,

r_j is the probability that the item will be repaired at base j, and

n is the number of bases.

If the average length of time required to accomplish a depot repair action on an item is DRT, then the expected number of demands placed upon the depot (λT_D) during the time DRT is:

$$\lambda T_D = EDD \cdot DRT$$

It is now possible to state the expected number of depot backorders (EBD) for a given depot stock level as:

$$EBD = \sum_{x=d+1}^{\infty} (x-d) \cdot p(x|\lambda T_D)$$

where,

x is the number of demands,

d is the depot stock, and

$p(x|\lambda T_D)$ is the probability of x demands over the length of DRT.

METRIC yields an optimal distribution of available assets to minimize expected systems backorders. The METRIC objective function can be stated as:

$$\text{Minimize} \sum_{k=1}^{m} B(S_k, S_o)$$

$$\text{Subject to} \sum_{k=0}^{m} S_k = TS$$

where,

m is the number of bases;

S_k is the stock level at base k;

S_o is the stock level at the depot;

TS is the system stock level; and

$B(S_k, S_o)$ is the expected backorder at a random point in time at base k, when the depot stock level is S_o and the base level is S_k.

The Air Force Implementation of METRIC

In 1962, The RAND Corporation collected six months of demand data for a sample of 2802 recoverable items from Andrews AFB. This data was used as input to a base stockage model ". . . *to compute item stock* levels required to achieve a range of aggregate fill rates [4:v]." Demands for these items over the following six-month period were compared to stock levels computed by the model. Test results showed the actual fill rates differed by less than 5 percent from the target fill rates determined by the model (4:v-vi). Continued efforts by RAND and the Air Force resulted in additional tests being conducted at Hamilton AFB, in 1965, and George AFB, in 1966. In October 1967, HQ AFLC recommended that METRIC be adopted for Air Force use. Under the direction of HQ USAF, AFLC personnel conducted a service test of METRIC at the Warner Robins ALC from November 1968 to December 1969.

In early 1975, METRIC techniques were incorporated into the Recoverable Item Requirements System (DSD D041) and became known as the Recoverable Consumption Item Requirements System Variable Safety Level (VSL) (DSD D041A). Item buy requirements were being computed based on an optimal technique; however, the distribution process continued to satisfy customer-computed demands on a first-come-first-served basis without regard to any optimal allocation of

the buy requirement. In August 1975, HQ AFLC and the Air Force Data System Design Center (AFDSDC) personnel recommended a three-phase approach of implementing a technique to optimally distribute assets:

Phase 1--centralized computation of base levels.

Phase 2--directed distribution of assets.

Phase 3--directed lateral supply between bases.

Phase 1 became the D028 system.

The D028 System

Since design efforts began on the D028 system, conflicts between the theoretical aspects of METRIC and the "real" world of the Air Force supply system have been numerous. The first deviation from the optimal allocation process was the requirement to satisfy authorized base negotiated levels. Negotiated levels are those levels of stock required to support the base mission, but for which usage experience does not adequately predict future needs. The next significant change was directed toward the determination of worldwide item totals to be allocated by the D028 system. Originally, available assets were intended to be used to determine the levels allocated. However, a consensus of an operational definition of available assets could not be reached. A major point of disagreement centered around the assets due-in from the production contractors and the D028 system's scheduled monthly processing

cycle. If production assets arrived at the ALC shortly after a D028 processing cycle and had not been included in the system's available assets total, the assets would be available to other services and foreign military sales countries without the Air Force bases being considered as needy customers. On the other hand, including production assets in the D028 system's available asset total could create system backorders, if the contractor failed to deliver the assets for an extended period of time. To overcome this problem, the decision was made to use a portion of the D041 system requirements quantities in the D028 system allocation process, instead of the available assets. These quantities represent the requirements computed in support of Air Force bases needs; a repair cycle requirement, an order shipping requirement, a negotiated level requirement, a depot safety level requirement, and the base safety level requirement. Third, excessive D028 system run times forced a reliance on a search algorithm versus an enumerative computation of depot/base allocations as a means of determining the final allocation position. This technique may yield non-optimal solutions.

The objective of the D028 system, like METRIC, is to optimally determine base stock levels for each item in order to minimize the expected number of system backorders for the item:

$$\text{Minimize} \sum_{k=1}^{m} B(S_k, S_o)$$

$$\text{Subject to} \sum_{k=0}^{m} S_k = TS$$

where,

S_k is the item stock level at base k;

S_o is the item stock level at the depot;

TS is the item system stock level;

$B(S_k, S_o)$ is the expected backorders at a random point in time for the item at base k, when the base's level is S_k and the depot level is S_o; and

m is the number of bases.

Triwush (12:36-47) shows that the backorder equation used by Sherbrooke (11:14) can be transposed to arrive at the D028 system's stated objective function.

The D028 system operates with the following constraints and assumptions:

1. The base computed stock levels may be minimum and maximum constraints as determined by negotiated levels.

2. No base-to-base support is possible.

3. Item demand patterns are described by a logarithmic Poisson probability distribution.

Assuming a logarithmic Poisson probability distribution gives demand probabilities of (2:p.A4-05):

$$p(x) = \left(\frac{(k+x-1)!}{(k-1)!x!}\right) \cdot \left(\frac{q-1}{q}\right)^{x} \cdot \left(\frac{1}{q}\right)^{k}$$

$q>1, \; k>0, \; x=0,1,2,\ldots$

where,

$p(x)$ is the probability of x demands,

q is the variance-to-mean ratio, and

k is equal to the mean plus $(q-1)$.

The reference to the mean refers to the mean number of demands over the time period of the computation: the depot repair cycle time when computing $p(x)$ at the depot, or the base average resupply time when computing $p(x)$ at the base. The variance-to-mean ratio (q) is an empirically established relationship described in HQ AFLC/XRS Working Paper 49, Estimating the Variance-to-Mean Ratio for Recoverable Items in the ALS Marginal Analysis Algorithms, March 1973. The ratio is determined using a regression equation:

$$q = 1.169496 \cdot (\text{Mean})^{0.3124585} \qquad [2:A4-06].$$

The objective function and the demand probability distribution provide the foundation for the D028 system algorithm process. The next logical step in this process is the determination of base stock levels. Two major variables must be defined before the allocation process begins: the depot delay time of Average Depot Delay per Demand (ADDD) and the expected number of base backorders, $B(s)$.

To determine the ADDD, it is necessary to compute the expected number of demands placed upon the depot over the average length of time required to perform repair actions (DPMEAN):

$$DPMEAN = DRC \sum_{k=1}^{m} (DDR_k \ (1-PBR_k))$$

where,

DRC = depot repair cycle days,

DDR_k = daily demand rate at base k,

PBR_k = base repair fraction at base k $\left(= \frac{\%\ \text{base-repaired}}{100}\right)$

m = number of bases [2:p.A4-10].

The depot repair cycle days (DRC) is provided to the D028 system, for each item, by means of a mechanical interface with the D041 system. Bases' daily demand rates (DDR) and repair factions (PBR) are provided by each base to the appropriate ALC and in turn are provided to the D028 system by means of a mechanical interface with the Central Knowledge Subsystem (D143H). The expected number of depot backorders, $B(S_o)$, for a given depot stock level must be computed:

$$B(S_o) = \sum_{x=S_o+1}^{\infty} (X-S_o) \cdot p(x)$$

where,

S_o = depot stock level,

x = number of demands,

$p(x)$ = probability of x demands over the length of the depot repair cycle.

A recursive formula derived from the above equation is actually used to compute backorders or expected number of delays. The recursive equation is shown below:

$$B(S_o) = B(S_o-1) + \left[\sum_{x=0}^{S_o-1} p(x)\right] -1$$

where,

B(0) = DPMEAN [2:p.A4-11].

It can be shown that B(0) equals the DPMEAN:

$$\sum_{x=s+1}^{\infty} (x-s) \cdot p(x) = \sum_{x=0}^{\infty} x \cdot p(x)$$

which equals the mean of x, when s is zero.

Now the depot delay can be described as:

$$\text{ADDD} = \frac{B(S_o) \cdot \text{DRC}}{\text{DPMEAN}} \quad .$$

Before the expected number of depot backorders, B(S), can be stated, it is necessary to determine the expected base demands (BSMEAN). The BSMEAN equals the base daily demand rate times the sum of the demands

satisfied at the base and the demands which must be satisfied from depot stock. With this information on the BSMEAN, the same formula used to compute $B(S_o)$ can now be used in deriving $B(s)$, where $(s-1)$ equals the current base stock level.

$$B(s) = B(s-1) + \left[\sum_{x=0}^{s-1} p(x)\right] - 1$$

$$B(s-1) - B(s) = 1 - \sum_{x=0}^{s-1} p(x) \qquad [2:p.A4-14].$$

Given that (S_j-1) equals the current base stock level at base j, we can see that $[B(S_j-1) - B(S_j)]$ is actually the decrease in expected base backorders which would be realized at base j if one more item was added to the base stock level. When an item is available for allocation, the D028 system calculates the $[B(S_j-1) - B(S_j)]$ value for each user and allocates a number to the user with the greatest change in expected backorder. It must be remembered that base levels will be constrained by the minimum and maximum levels discussed earlier. By doing this for each unit available for allocation, the D028 system objective function is satisfied.

Preferential Support

In November 1977, HQ USAF authorized a C-factor value of two (2.0) in the base computation of safety levels for all USAFE and selected PACAF bases. As previously stated, the purpose of this increased C-factor is to improve the readiness capabilities of these bases (9:3). The improved readiness capability is accomplished by providing a larger base demand level than would be generated by usage data. The methods for computing the safety level and the demand level were discussed at the beginning of this chapter. In July 1979, HQ USAF directed the D028 system design be modified in accordance with existing Air Force policy, to provide increased stock support (preferential support) to authorized Air Force locations (8).

To satisfy the new requirement, the D028 system logic was modified to weight backorders in the objective function more heavily for those bases authorized C-factors greater than one (1.0). In the D028 System Functional Description (2:pp.A4-12 and A3-13), the weighting value is explained. The algorithm factor used during the allocation process is defined as:

$$\text{FACTOR} = \frac{\sum_{x=0}^{S_C-1} p(x)}{\sum_{x=0}^{S_1-1} p(x)} .$$

Where S_c is the base's AFM 67-1 demand level; a level computed using the authorized C-factor. The S_1 is the base's AFM 67-1 demand level computed using a C-factor of 1. It is now clear, the FACTOR is the ratio of fill rates.

If the S_1 value equals zero, then the factor is computed to be the ratio of the expected fill rates, 97 percent/84 percent, at each C-factor value (2:p.A4-13).

The D028 system maintains the D041 system computed requirements in two main portions, that portion which can be supported by usage experience, repair times, and negotiated levels (MAQR) and a portion which supports base safety levels (MAQS). The allocation process only applies the weighting values to the MAQS portion after exhausting the MAQR portion (10:Atch). The algorithm factor is applied to the expected backorder reduction of a C-factor 2 user during the allocation of the MAQS portion.

Research Objective Restated

The objective of this study is to perform an empirical test and comparison of alternative procedures to determine their probable effect on user support, so as to provide Air Force management with a sound basis to decide on a procedure which will provide a desirable level of enhanced support to preferred users, without allowing an unacceptable degradation of support to non-preferred users.

Research Question

Is there a statistically significant difference in the median computed fill rates for the different alternative procedures of providing preferential support in the D028 algorithm?

Summary

This literature review has concentrated on the current procedures for computing base stock levels, METRIC, the Air Force use of METRIC, the D028 system, and the recent improved support capability requirement imposed on the D028 system. This review indicated a need for more information on how to incorporate a C-factor-like effect into the D028 system algorithm. This need provides the impetus for the research effort.

CHAPTER III

METHODOLOGY

Introduction

In order to effectively use available resources, the decision was made to use the items included in the D028 system service test data bases as a starting position for creating the research data files. Air Force base personnel throughout the world and the SA-ALC have been collecting usage data for selected items for approximately eighteen months. The decision was also made to use the D028 system Levels Computation Program (GZPC4D028, referred to hereafter as C4) to determine user level allocations for all alternative approaches selected for investigation. A third decision was made to modify base and item data instead of changing the C4 program logic to accomplish the alternative approaches. This decision was made in an effort to enhance the integrity of the research effort.

The literature review, guidance provided by Mr. Henry Triwush (HQ AFLC/XRS), and suggestions by Major James Masters (AFIT/LSB) resulted in the definition of three alternative approaches for accommodating the preferential support requirement in the D028 system:

1. Total D041 Quantity Approach.

2. Minimum Safety Level Approach.

3. Ninety-seven Percent Fill Rate Approach.

For comparison purposes, a base line using only C-factor values of one (1.0) for all users and the current D028 system (Standard D028 System Approach) being service tested at the SA-ALC were included in the research effort.

Comparison of the different alternative procedures was achieved by statistically testing the user fill rates resulting from the different procedures.

Research Items

Items selected for use in the D028 system service test were not randomly selected from the population of items for which SA-ALC is the designated ICP. Approximately one-half of the items were selected by HQ AFLC and the other one-half by the Major Air Commands. Guidelines (5) were provided to the Major Commands in an effort to have the test items represent the general characteristics of the item population.

Two data files were obtained from the SA-ALC reflecting the D028 system service test files as of November, 1980. One file, the Parameter Control Data File (file identification of GZIC2A1), included item related data, such as standard repair cycle times and order and shipping times. Other data included in the file were item identification (stock

number, NSN), depot repair time, D041 system requirements quantities, and others (3:pp.A5-8 and A5-9). Appendix A contains a list of the data elements included in the file. The other file, the Item/User Computation Parameter File (file identification of GZIC2A2), included user type data for the items in the GZIC2A1 file. Data included in this file were NSN, user identification, authorized C-factor, daily demand rate, percent of base repair, negotiated levels, and others (3:p.A5-13). Appendix A contains a list of the data elements included in the file. These files included all D028 system test items.

Since the research effort was only interested in the question of preferential support, the GZIC2A1 and GZIC2A2 files were processed to select only those items having at least one authorized C-factor two (C-2) user. After this process, a file, equivalent in structure to the GZIC2A1 file, contained two hundred and twenty-four (224) item records. A file, equivalent in structure to the GZIC2A2 file, contained five thousand and one (5001) user records. Two additional modifications were required to these files before the research files were established.

The D028 system logic had been changed, since November 1980, to eliminate some users from the allocation process. Users eliminated were those not having a reported daily demand rate greater than 0.0055, a demand level equal to zero (0.0), and no reported negotiated levels. The

second modification to the files required eliminating one item record because no user requirement had been computed by the D041 system. The research data files, C2A1 and C2A2, included two hundred and three (203) item records and thirty-six hundred and seventy-two (3672) user records, respectively. Appendix B is a list of the stock numbers and the number of users used during the research effort. Ranges of item characteristics for the items included in the research effort are given in Table 1. The D041 system standard BRCT and O&ST values are used in the C4 program whenever user data is not available.

TABLE 1

RANGES OF CHARACTERISTICS FOR RESEARCH ITEMS

Item Characteristic	Range
Number of item users	1-150
Number of C-1 users	0-142
Number of C-2 users	1-17
Total D041 requirements	3-2249
User repair cycle times (BRCT)	0-99
User order and shipping times (O&ST)	0-84
Average BRCT	0-29

Computer Program Information

The C4 program used during the research effort reflects the D028 system logic as of February, 1981. During the investigation of the different alternative approaches, the C4 program logic remained functionally as received from the SA-ALC and was used to compute all user fill rates. FORTRAN computer programs were written to manipulate the items and user data as required to accomplish the alternatives selected for investigation.

Techniques

Research Base Line

A research base line was established for comparison purposes. This was accomplished by modifying the C2A2 file, before running the C4 program to determine user base line fill rate values. Modification of the C2A2 records required all C-factor values of two be changed to a value of one. In this manner, fill rate values reflect optimal values, except where constrained by user negotiated levels and the C4 program logic for satisfying negotiated levels. That is, results of the base line indicate what fill rates would be expected if no attempt was made to provide preference to any users.

Standard D028 System Approach

This approach represents the policy decision to satisfy the preferential support requirements by

distributing the safety level quantity computed in the D041 requirement system so as to favor C-2 users over C-1 users. The D028 system logic implements this decision and is being service tested at the SA-ALC. Within the C4 program, users authorized C-factor values greater than one (C-2 user) have their backorders weighted during the allocation process of the D041 safety level quantity, that is, for those assets which have been selected for procurement over and above the average pipeline requirements, because of relatively favorable benefit-to-cost ratios.

Total D041 Quantity Approach

This approach applied the weighting factor technique of the D028 system to the total D041 system requirements quantity. In other words, the D041 system requirements quantities are viewed as a single quantity. The C2A1 file records were modified and the modified file was processed by the C4 program. The C2A1 file records included two D041 system requirements quantities; a D028 Requirement OIM Quantity (OIM QTY) and a D028 Base Variable Safety Level Quantity (VSL QTY). The OIM QTY represents the sum of the requirements computed in the D041 system in support of base repair cycle, order and shipping, negotiated levels, depot repair cycle, and the depot safety level. The VSL QTY represents the requirements computed in the D041 system in support of the bases' safety levels, that is, those

assets which are identified as cost effective to procure in addition to pipeline requirements. Modification of the C2A1 file records was accomplished in two steps:

1. The VSL QTY was set equal to the sum of the VSL QTY and the OIM QTY.

2. The OIM QTY was set equal to zero.

No change was required to the C2A2 file data prior to running the C4 program.

Minimum Safety Level Approach

A pseudo-minimum level was computed for all C-2 users. The pseudo-minimum levels were calculated according to the procedures outlined in AFM 67-1 and stated in Chapter II:

$$C\sqrt{3(\text{Repair Cycle Qty} + \text{O\&ST Qty})}\ .$$

In the calculation of this level, user data was used whenever possible; otherwise, standard item data in the C2A1 file was used. If the item was identified in the C2A1 file as a low cost item, a 0.90 value was added to the level quantity; otherwise, a 0.50 value was added.

The users C2A2 records were modified to reflect a minimum level equal to the sum of the recorded negotiated levels and the integer part of the pseudo-minimum level. The other recorded negotiated levels were set equal to zero. The C2A1 file records were modified as follows:

1. The OIM QTY was set equal to the sum of the OIM QTY and the VSL QTY.

2. The VSL QTY was set equal to zero.

This action was required to eliminate the preference provided in the C4 program by use of the weighting factor technique for the VSL QTY.

Ninety-seven Percent Fill Rate Approach

This approach was developed assuming that the ninety-seven (97) percent fill rate for C-2 users stated in AFM 67-1 and discussed in Chapter II, for the safety level requirement, is the desired level of support applicable over the C-2 users' total requirements. That is, C-2 users' requirements would be supported to a 97 percent fill rate position. This approach required the use of the modified C2A1 file used for the Minimum Safety Level Approach and the research C2A2 file. Using the modified C2A1 file, which considers the total D041 quantity as OIM, prevented the C-4 program logic from giving preference to C-2 users.

After running the C-4 program, C-2 users failing to achieve a 97 percent fill rate had their C2A2 recorded minimum levels adjusted to reflect a value of one greater than their allocated level. The C4 program was rerun using the adjusted C2A2 file. This process was repeated until all C-2 users achieved a 97 percent fill rate position for all items.

Performance Measures and Item Stratification

User fill rates were used as a measure for comparison purposes of the different approaches for satisfying the D028 preferential support requirement. The use of backorders as a measure of user support fails to provide a concise evaluation across users. A user may have a larger expected backorder, yet have a large number of assets available to satisfy demands. In AFM 67-1 (14:p.11-12), support effectiveness or performance is defined in terms of percent support (fill rate). Fill rate is the probability that a user demand will be satisfied by issuing on-hand stock. In mathematical form:

$$\text{Fill Rate} = \sum_{x=0}^{s-1} p(x)$$

where,

x is the demand for the item, and

s is the item stock level.

Another reason for using the fill rate was the fact that the C4 program provides the user's computed fill rate as an output element.

It is unrealistic to discuss preferential (enhanced) support to selected users without considering the degradation of support imposed upon the other users. Therefore, the research effort investigated the different approaches with

regard to the preferred (C-2) and non-preferred (C-1) customers.

The ratio of the D041 system total requirements to computed pipeline quantity was used to group the items for statistical purposes. The pipeline quantity represents that quantity required to support the expected demands placed upon the depot by all users and the demand placed upon the users during user repair times and depot resupply times. The pipeline quantity is expressed mathematically as:

$$\text{Pipeline Quantity} = \text{DRC} \cdot \sum_{j=1}^{n} [\text{DDR}_i \cdot (1-\text{PBR}_i)]$$

$$+ \sum_{i=1}^{n} \text{DDR}_i \left\{(\text{BRCT}_i \cdot \text{PBR}_i) + (1-\text{PBR}_i)[(\text{O\&ST}_i) + (\text{ADDD} \cdot \text{DRC})]\right\}$$

Both parts of the equation have been previously discussed in Chapter II. The first part is the depot mean and the second part is the sum of all users expected demands for a given level of stock at the depot. The computed pipeline quantity for each item assumed the depot level of stock to be equal to the depot mean and results in a 50 percent users fill rate.

The two hundred and three (203) items (Appendix B) included in the research effort were divided into three groups, based upon the ratio values. Appendix C is a list

of the items in each group. Seventeen (17) items were identified for which the D041 system requirement was less than the sum of the user negotiated levels, either before or after the application of the alternative approaches. These 17 items were excluded from further considerations in this research effort. These items are denoted with an asterisk in the group listings. The number of users, C-1 and C-2, the ratio cutoffs, and the number of items in each group are shown in Table 2.

TABLE 2

GROUP CHARACTERISTICS

Group	Number of C-1 Users	Number of C-2 Users	Ratio Lower Cutoff	Ratio Upper Cutoff	Number of Items
Group 1	95	13	0.0	.79999	6
Group 2	950	156	.80000	2.00000	52
Group 3	1965	375	2.00001	Inf.	128

Groups 1 and 3 were excluded from the statistical procedures, because of biasing influences. Application of the different approaches to items having a very small ratio would result in extreme degradation of support for C-1 users. On the other hand, the application of the different approaches to items having a larger ratio would have minimal effects on support for all users; that is, items

with high ratios generally have very high fill rates regardless of whether or how preferred support is attempted.

Analysis of User Fill Rates

An initial review of the user fill rate distributions indicated that the standard normality distribution assumptions were not warranted. The fill rates were skewed to either the high (100 percent) or the low (0 percent) values, with few users located in the middle range. Nor could any distribution be found that represented the fill rate distributions. For these reasons, the median fill rate values for each item across its users was used as the fill rate for an item.

Without an underlying distribution for the item fill rates, a distribution-free statistical procedure was required to test for significant differences between the median fill rates resulting from the application of the different approaches. A distribution-free test developed by Friedman, Kendall, and Babington Smith (6:136-146) was used to perform this test. This procedure makes three assumptions:

A1. We take the model to be

$$X_{ij} = \mu + \beta_i + T_j + e_{ij},$$

$$i=1,\ldots,n; \; j=1,\ldots,K, \qquad (1)$$

Where μ is the overall mean, β_i is the block i effect (the β's are unknown nuisance parameters), T_j is the unknown treatment j effect, $\sum_{i=1}^{n} \beta_i = 0$, and $\sum_{j=1}^{k} T_j = 0$.

A2. The e's (error variables) are mutually independent.

A3. Each e comes from the same continuous population [6:139].

In this study, the treatment, T_i, is the different approach. Each individual item is assumed to have an unknown nuisance parameter, β_j, as a result of its unique ratio of D041 system assets to pipeline requirements. This procedure tests the hypothesis:

$$H_0: \ T_1 = T_2 = \ldots, = \ T_k$$

against the alternative that the T_i's are not all equal (6:139).

An α value of 0.05 was used in this procedure. Rejection of this hypothesis would lead to a second procedure for determining which approach was different.

The second procedure was a distribution-free multiple comparison based upon the Friedman Rank Sums, attributed to Wilcoxon (6:a5a). This procedure permits the multiple comparisons for all approaches (treatments T_1 - T_5) to determine if there are significant differences,

at the 0.05 level, for the fill rates resulting from the different approaches.

Summary

A research data base, C2A1 and C2A2 files, was constructed from data provided by the SA-ALC. These files were modified, as required, for the application of three alternative approaches for satisfying the requirements of preferential support to selected users:

1. Total D041 Quantity Approach.
2. Minimum Safety Level Approach.
3. Ninety-seven Percent Fill Rate Approach.

These items were divided into three groups based upon a ratio of the D041 system requirements to a computed pipeline quantity. Only Group 2 items were used to apply distribution-free procedures for determining if a significant difference of the median fill rate values resulted from the application of the different approaches.

CHAPTER IV

RESEARCH RESULTS

Overview

The five approaches were executed using the research data base described in Chapter III. The output results were then stratified, giving an overall view of user fill rates within the groups and between C-1 and C-2 users. To further summarize what level of support was provided by each approach, user fill rates were reviewed to determine what percentage of the C-1 and C-2 users within each group actually reached the fill rate goals of 84 and 97 percent outlined in AFM 67-1 (15:p.11-7).

Distribution-free statistical tests were performed using the Group 2 items. Test results showed a significant difference at the 0.05 level between the median fill rates across all approaches. Further nonparametric testing was conducted to determine differences between each approach.

Specific Results

Percentage of Fill

Table 3 provides an overview of the research results. This table reflects the lowest, median, and the highest percentage of fill (fill rate x 100) computed, by category of user (C-1 or C-2) for all items within a group and for all

TABLE 3

OBSERVATIONS FOR GIVEN GROUPS AND C-FACTORS*

		Group 1		Group 2		Group 3	
		C-1	C-2	C-1	C-2	C-1	C-2
BASE LINE	Low	0.00	0.00	0.00	0.00	0.00	44.61
	Med	0.01	0.52	92.08	95.25	99.54	99.37
	High	100.00	99.76	95.25	100.00	100.00	100.00
D028 SYS	Low	0.00	0.00	0.00	0.00	0.00	44.61
	Med	0.03	0.42	91.92	95.46	99.54	99.38
	High	100.00	99.76	100.00	100.00	100.00	100.00
TOTAL D041	Low	0.00	0.00	0.00	0.00	0.00	44.61
	Med	0.00	0.69	91.92	95.46	99.54	99.38
	High	100.00	99.76	100.00	100.00	100.00	100.00
MIN LVL	Low	0.00	8.77	0.00	45.26	0.00	69.55
	Med	0.00	69.76	91.46	96.18	99.53	99.43
	High	100.00	99.98	100.00	100.00	100.00	100.00
97% FILL	Low	0.00	97.04	0.00	97.07	0.00	97.04
	Med	0.00	97.85	91.04	98.58	99.54	99.58
	High	100.00	99.76	100.00	100.00	100.00	100.00

*listed as percent of fill.

five approaches. That is, for all C-2 users of the items in Group 1 and after the application of the Base Line Approach. The lowest percentage of fill for any of these users was 0.00, the median percentage of fill for all of these users was 0.52, and the highest percentage of fill for any of these users was 99.76.

In comparison of C-1 or C-2 users, for items in Groups 1, 2, or 3, and across the Base Line, D028 System, and the Total D041 Quantity approaches, small changes in the user percentages are observed. Small user percentages are also seen in the C-1 users for all groups across the Minimum Safety Level and the Ninety-seven Percent Fill Rate approaches. The largest changes in the C-2 user percentages occur in the lowest and median percentages for Group 1 items and across the Total D041 Quantity, Minimum Safety Level, and the Ninety-seven Percent Fill Rate approaches.

AFM 67-1 Fill Rate Objectives

Table 4 displays the percentages of users satisfying the fill rate objectives outlined in AFM 67-1 (15: p.11-7). These fill rate objectives are 84 percent for C-1 users and 97 percent for C-2 users. As was Table 2, Table 4 is by category of user (C-1 or C-2) for all items within a group and for all five approaches. These percentages were calculated as follows: the number of users for a given category (C-1 or C-2), for all items within the group,

TABLE 4

PERCENT OF USERS WITH EXPECTED FILL RATES EQUAL TO OR GREATER THAN 67-1 GOALS*

	Group 1		Group 2		Group 3	
	C-1	C-2	C-1	C-2	C-1	C-2
BASE LINE	1%	8%	73%	35%	97%	78%
D028 SYS	1%	8%	73%	36%	97%	78%
TOTAL D041	1%	8%	73%	36%	97%	78%
MIN LVL	1%	8%	72%	42%	96%	80%
97% FILL	1%	100%	69%	100%	94%	100%

*These goals are 84 percent for C-1 users and 97 percent for C-2 users.

achieving the objective (84 or 97 percent) divided by the total number of users for that category, for all items within the group.

The percentages of C-1 or C-2 users satisfying the objectives remain unchanged for items in Group 1, 2, or 3, and across the Base Line, D028 System, and the Total D041 Safety Level approach. In all other cases, changes in user percentage are indicated. As expected, the C-2 user percentage for all groups after application of the Ninety-seven Percent Fill Rate approach is 100 percent.

Statistical Testing of Median Fill Rates

Testing for Equality of Fill Rates

The distribution-free procedures were only applied to the items within Group 2, using the median fill rate values for each user category (C-1 or C-2). Referring to Group 1 in Table 2, there is no managerially significant difference between the percentages for the Base Line, D028 System, and the Total D041 Quantity approaches for the C-2 users. It is also clear that a sizeable difference does exist for the lowest and median C-2 user percentages between the Minimum Safety Level and the Ninety-seven Percent Fill Rate approaches. Clearly for Group 3, several differences are apparent; however, most of the C-2 user percentage differences are in the first decimal position and are not managerially significant. For these reasons, the statistical procedures were only applied to the Group 2 items. It is not clear for this group whether the observed differences are statistically significant or merely chance results.

In the application of the Friedman, Kendall and Babington Smith (6) procedures, the five approaches were viewed as treatments for purposes of performing hypothesis testing, at the 0.05 level:

H_0: $T_1 = T_2 = T_3 = T_4 = T_5$;

H_1: Not all T's are the same.

Where T_j = treatment effect.

The degrees of freedom is equal to k-1, where k is the number of treatments; therefore, the degrees of freedom is 4. The statistic S' was computed as 74.40 for the C-1 users and 13.01 for the C-2 users.

The decision rule is:

reject H_0 if $S' \geq \chi^2(k-1,\alpha)$;

accept H_0 if $S' < \chi^2(k-1,\alpha)$;

and χ^2 (4,0.05) = 9.49.

Therefore, since:

S'(C-1 users) = 74.40 > 9.49, reject H_0.

Reject the hypothesis that the median fill rates for the C-1 users are equal across the five approaches. In a similar manner:

S'(C-2 users) = 13.01 > 9.49, reject H_0.

Reject the hypothesis that the median fill rates for the C-2 users are equal across the five approaches.

If the decision had been made to use an α value of 0.01, the χ^2 value used in the test would have been 13.28. Under this condition, the hypothesis would have been rejected for C-1 users and accepted for C-2 users. Clearly, the results of the statistical procedures are significant at a higher α value than 0.05.

Pairwise Comparison Approaches

Since the previous test indicated that at least one approach led to fill rates which were significantly different from the rest, the multiple pairwise comparison of all treatment effects was conducted. The results of those procedures are summarized for fill rates for C-1 users in Table 5 and for fill rates for C-2 users in Table 6. These tables indicate the achieved statistical significance of the difference between treatment effects or approaches. For example, Table 6 indicates that a hypothesis that there was no difference between median fill rates achieved by C-2 users in Group 2 under current D028 preference procedures and those achieved with the Ninety-seven Percent Fill Rate approach would be rejected at an α of .0001.

TABLE 5

GROUP 2 (C-1) α LEVELS OF SIGNIFICANCE OF TREATMENT DIFFERENCES*

	BASE LINE	D028 SYS	TOTAL D041	MIN LVL	97% FILL
BASE LINE	-	N	N	.01	.0001
D028 SYS	-	-	N	.025	.0001
TOTAL D041	-	-	-	.025	.0001
MIN LVL	-	-	-	-	.05
97% FILL	-	-	-	-	-

*N shows no significant differences between the treatments.

TABLE 6

GROUP 2 (C-2) α LEVELS OF SIGNIFICANCE OF TREATMENT DIFFERENCES*

	BASE LINE	D028 SYS	TOTAL D041	MIN LVL	97% FILL
BASE LINE	-	N	N	.025	.0001
D028	-	-	N	N	.0001
TOTAL D041	-	-	-	N	.0001
MIN LVL	-	-	-	-	.0005
97% FILL	-	-	-	-	-

*N shows no significant differences between the treatments.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Research Review

Research Motivation

This research effort is the result of recognizing the need for more effective management of scarce logistics resources in order to provide the Air Force combat capability required to maintain our national security. In support of this combat capability, it is essential that the right thing be in the right place, and at the right time. These are the functions satisfied by the logistics supply system.

One part of this large and complex supply system, the D028 system, is undergoing a service test at the SA-ALC. The D028 system is a link to the future with regards to the management of scarce logistics resources. The D028 system uses a modified version of METRIC as a means of determining near optimal user allocations of the D041 system item requirements to achieve minimum system backorders for each item.

Recent HQ USAF direction has necessitated changes to the D028 system algorithm to ensure preferential support to

selected USAFE and PACAF locations. This preferential support is accomplished through the use of a backorder weighting technique.

Objective and Method

The objective of this research effort was the empirical testing of alternative approaches for satisfying the preferential support requirement within the structure of the D028 system. Three alternatives were selected for investigation:

1. Total D041 Quantity Approach.
2. Minimum Safety Level Approach.
3. Ninety-seven Percent Fill Rate Approach.

These alternatives, along with a Base Line and the Standard D028 System, were investigated using modified SA-ALC item and user data and a D028 system program.

The SA-ALC items were stratified into three groups based upon the ratio of the D041 system item requirements to a computed item pipeline quantity. Median user fill rates, across each item, were used as a measure of support effectiveness. Distribution-free techniques were used to test the hypothesis that the median user fill rates were equal across the five approaches and, subsequently, to find which specific alternatives provided significantly different fill rates.

Research Findings

Research results of the different approaches indicate either minor or major differences between the user (C-1 or C-2) lowest, median, and highest fill rates for Groups 1 and 3 across all approaches. Similar results were observed between the percentages of C-1 or C-2 users achieving the AFM 67-1 objective fill rates of 84 and 97 percent, respectively. For these reasons, the distribution-free techniques were used only for the items within Group 2.

Tests of significance resulted in rejecting the hypothesis that the user (C-1 or C-2) median fill rates were equal across all five approaches for items in Group 2. No significant differences between C-1 user median fill rates were calculated for the Base Line, D028 System, and the Total D041 Quantity approaches. The differences between the C-1 user median fill rates recorded for the Minimum Safety Level and the Ninety-seven Percent Fill Rate approaches when compared to the other approaches were significant, at the .0001-.05 levels. The C-2 user results were similar to the C-1 user results. The significance level range was .0001-.025 when the Minimum Safety Level and the Ninety-seven Percent Fill Rate approaches were compared to the other approaches.

Conclusions

The following conclusions are drawn from the research effort.

1. *No significant differences exist in the user median fill rates when comparing the Base Line, D028 System, and the Total D041 Quantity approaches.*

Test results failed to indicate any significant change in the level of support (enhancement) provided to the C-2 user median fill rates as a result of using the Base Line, the D028 System, or the Total D041 Quantity approaches. Nor was there any significant change in the level of support (degradation) provided to the C-1 user as a result of these three approaches. Therefore, if one of these approaches must be used to satisfy the preferential support requirement, the approach which provides the simplest, most straightforward method of determining user allocations should be selected.

2. *The Minimum Safety Level Approach provides unsatisfactory results for satisfying the preferential support requirement.*

Comparison of the Minimum Safety Level and the Base Line approaches provide significant differences for both preferred and non-preferred user median fill rates. The level of significance is .025 for the preferred users and .01 for the non-preferred users. For the sample items in this research, the Minimum Safety Level Approach is

an alternative which significantly affects system performance as measured by fill rates.

In the comparison of the Minimum Safety Level and the D028 System or the Total D041 Quantity approaches, no significant differences are observed in the preferred user median fill rates. However, significant differences at the .025 level were observed for the non-preferred users. However, it would be illogical to impose any degradation of support for non-preferred users without enhancing the preferred user support.

3. *The Ninety-seven Percent Fill Rate Approach provides significant enhancement of support for preferred users and significant degradation of support for non-preferred users.*

If the objective of the preferential support requirement is truly to satisfy those selected users to a 97 percent item fill rate position, only the Ninety-seven Percent Fill Rate Approach satisfies this requirement. Comparing this approach to the other approaches, the differences between the C-2 user median fill rates were significant between the levels of .0001 and .0005. However, the degradation of support provided to the non-preferred users was also significant, between the levels of .0001 and .05. Looking at the percentages of users (preferred and non-preferred) achieving the 84 and 97 percent fill rate objectives of AFM 67-1 permits another view of this approach.

As expected, the preferred user percentages show a change from 35 percent for the Base Line to 100 percent for the Ninety-seven Percent Fill Rate. A change of four percentage points (73 percent to 69 percent) was observed for the non-preferred users when comparing these approaches. The managerial decision which must be made is: Can non-preferred users complete their assigned missions with the degraded level of support imposed using this alternative?

Recommendations for Actions

The following recommendations are the result of this research effort.

1. *Conduct follow-on research to determine acceptable percentages of fill rates for preferred users.*

This research would use the functional logic of the Ninety-seven Percent Fill Rate alternative and vary the item fill rate percentage provided to preferred users. Results of this research are necessary for management to realize the degradation of support for non-preferred users resulting from the enhancement of support for preferred users.

2. *Eliminate the D041 system item requirements used for purposes of determining the D028 system user allocations.*

Of the two hundred and three (203) items used during this research, sixty-four (64) percent of the items had a

D041 system item requirement greater than twice the computed item pipeline quantity. Although the research data represents the SA-ALC position as of November, 1980, the apparently overstating of item requirements cannot be ignored. It is unrealistic to determine user allocations based upon questionable item requirements.

3. *Consider system available assets for use in the application of METRIC for determining user allocations.*

The application of METRIC in the distribution system appears to satisfy a current need of the Air Force, that is, the management of scarce logistic resources. Therefore, it is essential that a replacement for the D041 system item requirements be found in the shortest possible time frame. The original design of the D028 system included system available assets for the purpose of determining user allocations. Difficulties arose in operationally defining system available assets to the satisfaction of all interested parties. This problem seems minor compared to the overall problem of managing scarce logistics resources.

APPENDICES

APPENDIX A

DATA ELEMENTS

C2A1 FILE
(ITEM DATA)

D041 Cutoff Date

Standard Base Repair Cycle Time (BRCT)

Standard Order and Shipping Time (O&ST)

Manager Designator Code

Stock Number

Subgroup Code

Unit of Issue

Depot Repair Cycle Time

D021 Requirement Organizational Intermediate Maintenance (OIM) Quantity

D028 Base Variable Safety Level

ERRC

Item Cost Indicator

User Average BRCT

User Average O&ST

Number of Users

C2A2 FILE
(USER DATA)

Manager Designator Code

Stock Number

Subgroup Code

Stock Record Account Number

Routing Identifier

Demand Level

Daily Demand Rate

Percent Base Repair

ISSL Level

Minimum Level

Fixed Level

Maximum Level

Geographical Area

C-Factor

Average O&ST

BRCT

Airlift Code

APPENDIX B

RESEARCH ITEMS

MANAGER DESIGNATOR	STOCK NUMBER	TOTAL NUM USERS	C-FACTOR 2 NUM USERS	DO41 OIM QUANTITY	DO41 SAFETY LEVEL QTY	PIPELINE RATIO
GAB	4920010854155DQ	8	3	25	4	1.70300
GAB	4920010328095DQ	5	1	22	0	43.90800
GAC	6625010199977	5	1	44	50	10.12400
GAE	6625000037074	16	5	39	39	3.62700
GAE	6625000784718	7	2	8	11	2.82200
GAE	6625003506047	7	1	3	0	.91500
GAH	6625004223459	13	1	16	53	8.17900
GAH	6625004444064	20	2	34	41	6.39400
GAH	6625004878773	13	2	10	15	2.47300
GAH	6625005580059	1	1	1	2	6.41100
GAJ	6625001379077	7	2	35	3	4.71500
GAJ	6625003903851	6	1	11	0	4.65800
GAJ	6625010582419	7	2	27	0	6.11300
GAJ	6625010645906	6	2	49	5	3.24900
GAK	6625009117243	9	3	22	22	5.54000
GAK	6625009293951	4	2	4	9	6.39200
GAN	4920001122438DQ	5	1	12	0	6760.56300
GAN	6625004224289DQ	2	1	2	4	7.52300
GAN	6625004502020DQ	5	1	9	28	6.07600
GAQ	4920004444526DQ	4	1	2	6	6.24800
GAQ	4920004463482DQ	13	3	6	26	2.35600
GAQ	4920010145383DQ	12	2	27	3	3.17500
GAU	4920002283588DQ	7	2	5	13	7.05300
GAU	4920004023060DQ	2	1	3	6	12.49500
GAV	4920004600339DQ	4	2	5	11	4.59200
GAV	4920004973124DQ	3	1	11	18	7.16200
GAV	4920009236267DQ	1	1	9	11	36.24000
GAV	4920009276532DQ	7	2	31	56	4.05500
GAX	4920010389108DQ	7	2	28	3	5.47400
GAY	4920000429568DQ	5	2	3	9	4.06900
GAZ	4920003275297DQ	7	2	11	4	.95900
GAZ	4920010542754DQ	8	3	15	0	2.45000
GAZ	4920010545028DQ	7	2	11	4	1.10600
GAZ	4920010595118DQ	5	2	13	3	2.53300
GAZ	6625001614191DQ	7	2	7	13	3.15600

MANAGER DESIGNATOR	STOCK NUMBER	TOTAL NUM USERS	C-FACTOR 2 NUM USERS	D041 OIM QUANTITY	D041 SAFETY LEVEL QTY	PIPELINE RATIO
GA2	6625010525588	7	1	17	4	1.52200
GA2	6625010701817	5	3	15	4	1.54600
GA3	6625010514948	8	3	12	0	.60500
GA3	6625010536208	5	1	13	0	1.07600
GA4	4920010325317DO	6	1	13	0	5.94800
GBD	6645000700320	13	5	25	40	3.82600
GBD	6645000722128	28	11	56	90	2.42000
GBE	4920004973098	24	4	40	48	4.09500
GBE	4920007594706	7	2	7	20	5.42200
GBE	4920010418568	5	4	13	18	1.45900
GBF	4310001249688AX	2	1	5	7	4.66800
GBF	4310001860710AX	48	7	73	119	2.82100
GBF	4320007257386AX	23	4	21	49	3.25000
GBG	4920001245354	5	1	11	0	3606.55700
GBH	4920010116849	9	3	33	6	1.89400
GBH	4920010841586	5	2	15	3	2.44500
GBH	4920010841588	5	1	9	0	10.73500
GBJ	4920004104968	5	2	3	8	1.40600
GBN	6680001957338	10	2	14	30	4.54200
GBN	6680003336743	5	2	11	0	3.94700
GBN	6680009382155	3	1	2	6	3.72400
GBN	6680009840301	3	1	14	24	3.74100
GBT	6680008744609	7	2	12	16	3.23400
GBU	6685005534726	25	2	53	80	2.68800
GBU	6685010208749	15	1	35	77	4.64800
GBX	6685009382771	21	5	22	50	3.26900
GBY	6680000101377	6	2	7	9	2.98500
GCC	1680008098502	5	1	8	7	3.73900
GCE	1680009448371	7	2	15	26	4.16200
GCF	1680010370329	11	1	12	27	3.53500
GCG	1680006775227	20	2	35	58	4.56400
GCG	1680010325251	9	3	6	7	1.91200
GCP	1680010656999	11	1	20	0	.93300
GCQ	1680000680813	4	1	5	4	2.94700
GCQ	1680000736827	12	2	15	26	5.86400

MANAGER DESIGNATOR	STOCK NUMBER	TOTAL NUM USERS	C-FACTOR 2 NUM USERS	D041 OIM QUANTITY	D041 SAFETY LEVEL QTY	PIPELINE RATIO
GCO	1680005089183	5	2	11	0	1.93500
GDE	1680001398020XJ	4	1	32	19	1.20100
GEJ	1620001157436EV	4	2	3	0	.63000
GEJ	1680004400028EV	4	2	7	6	3.61200
GEJ	6110007869842EV	5	2	16	21	1.67600
GEJ	6685001791529EV	3	2	5	9	4.63200
GFJ	6615000694505EV	3	2	6	11	2.50700
GFA	1680009896083LS	3	2	8	4	2.48900
GFA	1680009797782LS	8	1	18	22	4.57000
GFD	1680005449140LS	13	1	16	23	2.91800
GFF	6220009458483	8	2	51	32	.97700
GFG	4120009128949	14	3	12	6	.42500
GFG	4120009465545	3	1	5	5	1.17100
GFG	4130018070601	5	1	14	15	1.95200
GFJ	6340007755798	5	2	3	7	1.15400
GFM	4810004917893	34	6	65	92	2.71400
GFM	4810007133144	24	3	29	54	4.23400
GFN	1680002860831LS	5	1	22	2	2.76200
GFR	5895007838243ZG	4	1	41	0	.18300
LAB	4920004902880	16	3	17	40	3.85600
LAB	4920009274484DQ	7	2	18	34	3.39100
LAB	6625001991679	66	3	148	207	1.29900
LAB	6625002700821	82	9	116	206	1.89500
LA2	4920001098374DQ	7	2	45	62	4.36600
LA2	4920009313228DQ	7	2	86	134	3.13900
LA2	4920010569722DQ	9	3	27	10	2.51800
LBH	4920004217726	47	9	75	52	2.19900
LBH	4920006591339	32	7	38	28	1.78700
LBN	6680000509718	6	1	44	38	1.69000
LBN	6680001921145	7	1	37	25	2.17400
LBN	6680005312988	23	2	19	35	4.21700
LBS	6680005511652	43	3	62	139	3.50700
LBS	6685006845176	65	15	175	260	1.99800
LBT	6680008786133	13	1	210	90	1.03500
LBV	6645001506526	130	8	618	628	1.29300

MANAGER DESIGNATOR	STOCK NUMBER	TOTAL NUM USERS	C-FACTOR 2 NUM USERS	D041 OIM QUANTITY	D041 SAFETY LEVEL QTY	PIPELINE RATIO
LBV	6680006510045	32	14	242	244	1.57200
LBX	6685005267864	131	7	230	606	2.36700
LBY	6680005511651	33	3	24	75	5.12500
LB3	6680009533234	28	3	52	99	4.16600
LB8	6685006841658	13	1	231	158	1.85300
LGA	1680007829382LS	34	9	50	116	4.11700
LGA	1680007335768LS	41	13	37	60	2.05200
LGA	1680007588152	37	2	34	81	3.23600
LGA	1680010520816LS	46	12	110	153	2.16400
LGB	1680000754925	27	5	35	63	3.55500
LGB	6220006171843	53	6	116	124	.66400
LGC	1680008220170	27	3	45	42	1.64200
LGG	4320007694539YZ	24	7	55	61	1.99100
LGG	6220009250505	9	2	60	41	1.20200
LT2	1680000229086	18	2	54	35	1.65500
LT2	1680010133229	43	6	99	102	1.75600
LT3	1680010033566	9	3	24	20	1.93900
LT3	6350002963328	27	7	69	110	3.52400
PAB	2925008056481RX	13	1	119	54	1.38500
PAC	2915001679145RX	13	1	121	58	1.70800
PAC	2915009370197RX	12	1	213	37	1.59200
PAC	2915009802701RX	12	1	137	95	1.42900
PAC	4820001689832RX	22	1	293	128	1.32200
PAE	2840000018343RX	4	2	23	14	.98100
PAE	4320007371397RX	13	1	53	41	1.79100
PAR	2840010041804TB	11	1	93	46	2.44600
PAY	2840001601685RX	12	1	13	10	1.10700
PCA	2925003276217PT	3	2	23	26	5.19900
PCA	2995002819796PT	3	1	41	51	3.69100
PCA	2995002952481PT	3	1	13	33	14.15100
PCA	2995005343027PT	5	2	7	68	16.51800
PCA	2995005390109PT	12	4	31	36	2.44400
PCD	2840003479686PT	10	2	5	30	6.72100
PCE	2840003266062PT	10	3	128	40	3.44800
PCE	2840003934437PT	11	3	18	17	1.22400

MANAGER DESIGNATOR	STOCK NUMBER	TOTAL NUM USERS	C-FACTOR 2 NUM USERS	D041 OIM QUANTITY	D041 SAFETY LEVEL QTY	PIPELINE RATIO
PCE	2840005167011PT	10	2	25	33	2.10600
PCF	2915010660264PT	11	4	105	46	1.18100
PCJ	2840010080563PT	10	4	13	0	.55900
PCS	2835010344772	3	3	27	0	.60000
PCV	2835003901884	9	2	17	5	1.09000
PCX	2840003522148PT	3	1	8	23	7.40000
PCY	2915010350276PT	10	3	205	35	1.17100
PEA	2915000740432	21	2	23	49	7.01400
PEC	2915001507312	7	2	18	20	3.18000
PEC	2915009719131	21	1	21	32	4.23300
PED	2915008715870	3	2	8	10	7.61300
PEG	2990005028693	59	4	79	166	3.37000
PEH	2915010097932	4	1	5	8	3.78800
PEH	2915010653500	8	3	17	0	.25000
PEH	2915010658525	7	2	40	13	3.10300
PEJ	2805004308835	9	3	10	14	2.87400
PEJ	2805005285958	81	10	161	148	1.97000
PEJ	2805009271579	24	2	11	16	2.45900
PEL	2915000599582	5	2	10	11	9.35400
PEL	2915002965828	13	3	21	32	3.00200
PFC	2840000104046RW	30	1	68	87	1.71200
PFC	2840000218168RW	6	1	12	15	3.16000
PFD	4810005283666RW	9	1	6	26	8.47500
PFF	2915007779017RW	32	2	29	71	2.69600
PFK	2840000097603RW	13	1	23	40	3.38400
PFK	2840008931321RW	12	1	17	12	3.99400
PFM	2835004973433	3	1	31	20	.91400
PFM	2920004624848YP	12	1	39	48	3.51400
PFT	2840007769779PH	5	2	103	61	1.61700
PFT	2915007748819PH	5	2	245	145	1.13900
PFX	2840006908966PE	3	1	77	29	1.01300
RAB	2840007023504RX	12	1	26	0	.17500
RAB	2915001065464RX	21	1	1670	579	1.21200
RAB	2995004750698RX	12	1	154	72	1.22800
RAC	2915001690244RX	12	1	112	45	1.40000

MANAGER DESIGNATOR	STOCK NUMBER	TOTAL NUM USERS	C-FACTOR 2 NUM USERS	D041 OIM QUANTITY	D041 SAFETY LEVEL QTY	PIPELINE RATIO
RAE	3110001807307RX	13	2	144	56	1.79300
RAY	2840007803486RX	21	1	269	9	1.36500
RAY	2840008335243RX	13	1	105	34	.93900
RAY	2840008698609RX	12	1	47	18	.65500
RAY	2840008698610RX	13	1	68	31	.68800
RCB	2915010753518PT	12	4	119	14	.86800
RCJ	2840005167023PT	12	3	558	172	.97700
RCJ	2840010882598PT	12	3	1024	363	1.73200
REA	2915000843949	34	2	41	83	3.87200
REA	2915009667731	15	3	32	51	4.21900
REC	2915007393047	35	4	51	95	2.55000
RED	2915005401801	37	4	43	77	3.32900
REL	2915003492159	48	3	75	177	3.19700
REL	4820001066610FS	38	4	56	130	3.71400
RFA	4320006740932RW	23	2	19	51	4.91600
RFB	2915007062719RW	33	4	34	61	2.41500
RFD	2915006263123RW	35	5	38	93	4.02900
RFF	2915004582767RW	63	6	273	270	2.05200
RFF	2915006165726RW	43	2	39	114	6.36900
RFF	2915010087399RW	25	5	27	18	1.35100
RFF	2925087062720RW	23	2	5	30	2.89300
RFH	2835006825352	55	10	55	100	2.06300
RFH	2835007973261	62	6	59	123	2.64300
RFH	2910002520167YP	23	2	94	92	2.42800
RFH	2910009108455YP	61	9	81	121	2.01500
RFH	2920010139867YP	87	17	95	193	2.47600
RFP	5930001688051YP	48	12	23	83	2.80800
RFT	2915009170849PH	14	3	34	42	2.35800

APPENDIX C

GROUP LISTINGS

GROUP 1

Manager Design.	Stock Number	Ratio
RAB	2840007023504RX	.17581
GFR	5895007838243ZG	.18337
PEH	2915010653500	.25039*
GFG	4120009128949	.42501
PCJ	2840010080563PT	.55919*
GA3	6625010514948	.60572*
GEJ	1620001157436EV	.63050*
RAY	2840008698609RX	.66543
LGB	6220006171843	.66454
RAY	2840008698610RX	.68889

GROUP 2

Manager Design.	Stock Number	Ratio
PCS	2835010344772	.80077*
RCB	2915010753518PT	.86821
PFM	2835004973433	.91436*
GAE	6625003506047	.91570
GCP	1680010656999	.93319
RAY	2840008335243RX	.93923
GA2	4920003275297DQ	.95999*
GFF	6220009458483	.97733
RCJ	2840005167023PT	.97755
PAE	2840000018343RX	.98133
PFX	2840006908966PE	1.01391
LBT	6680008786133	1.03553
GA3	6625010536208	1.07605*
PCV	2835003901884	1.09043
GA2	4920010545028DQ	1.10647*
PAY	2840001601685RX	1.10728
PFT	2915007748819PH	1.13986
GFJ	6340000755798	1.15453*
PCY	2915010350276PT	1.17170
GFG	4120009465545	1.17180
PCF	2915010660264PT	1.18199
GDE	1680001398020XJ	1.20176
LGG	6220009250505	1.20255
RAB	2915001065464RX	1.21265
PCE	2840003934437PT	1.22485*
RAB	2995004750698RX	1.22859
LBV	6645001506526	1.29348
LAB	6625001991879	1.29961
PAC	4820001689832RX	1.32298

Group 2--Continued

Manager Design.	Stock Number	Ratio
RFF	2915010087399RW	1.35155
RAY	2840007803486RX	1.36577
PAB	2925008056481RX	1.38594
RAC	2915001690244RX	1.40005
GBJ	4920004104968	1.40674
PAC	2915009802701RX	1.42913
GBE	4920010418568	1.45972*
GA2	6625010525588	1.52270
GA2	6625010701817	1.54661*
LBV	6680006518045	1.57234
PAC	2915009370197RX	1.59228
PFT	2840000769779PH	1.61750
LGC	1680008220170	1.64221
LT2	1680000229086	1.65505
GEJ	6110007869842EV	1.67652
LBN	6680000509718	1.69030
GAB	4920010054155DQ	1.70353
PAC	2915001679145RX	1.70877
PFC	2840000104046RW	1.71210
RCJ	2840010882598PT	1.73209
LT2	1680010133229	1.75619
LBH	4920006591339	1.78780
PAE	4320007371397RX	1.79161
RAE	3110001807307RX	1.79384
LB8	6685006841658	1.85303
GBH	4920010116849	1.89420
LAB	6625002700821	1.89587
GCG	1680010325251	1.91260*
GCQ	1680005089183	1.93523*

Group 2--Continued

Manager Design.	Stock Number	Ratio
LT3	1680010033566	1.93906
GFG	4130010070601	1.95285
PEJ	2805005285958	1.97093
LGG	4320007694539YZ	1.99103
LBS	6685006845176	1.99818

GROUP 3

Manager Design.	Stock Number	Ratio
RFH	2910009108455YP	2.01571
RFF	2915004582767RW	2.05230
LGA	1680007335768LS	2.05288
RFH	2835006825352	2.06321
PCE	2840005167011PT	2.10637
LGA	1680010520816LS	2.16412
LBN	6680001921145	2.17470
LBH	4920004217726	2.19910
GAQ	4920004463482DQ	2.35623
RFT	2915009170849PH	2.35838
LBX	6685005267864	2.36778
RFB	2915007062719RW	2.41550
GBD	6645008722128	2.42016
RFH	2910002520167YP	2.42865
PCA	2995005390109PT	2.44462
GBH	4920010841586	2.44557
PAR	2840010041804TB	2.44639
GA2	4920010542754DQ	2.45067*
PEJ	2805009271579	2.45929
GAH	6625004870773	2.47311
RFH	2920010139867YP	2.47638
GFA	1680009096083LS	2.48936
GEJ	6615000694505EV	2.50738
LA2	4920010569722DQ	2.51805
GA2	4920010595118DQ	2.53330
REC	2915007393047	2.55012
RFH	2835007973261	2.64346
GBU	6685005534726	2.68866

Group 3--Continued

Manager Design.	Stock Number	Ratio
PFF	2915007779017RW	2.69610
GFM	4810004917893	2.71483
GFN	1680002860831LS	2.76299
RFP	5930001688051YP	2.80841
GBF	4310001860710AX	2.82113
GAE	6625000784718	2.82244
PEJ	2805000430835	2.87411
RFF	2925007062720RW	2.89334
GFD	1680005449140LS	2.91854
GCQ	1680000680813	2.94741
GBY	6680000101377	2.98518
PEL	2915002965828	3.00251
PEH	2915010658525	3.10344
LA2	4920009313228DQ	3.13976
GA2	6625001614191DQ	3.15692
PFC	2840000218168RW	3.16082
GAQ	4920010145383DQ	3.17516
PEC	2915001507312	3.18054
REL	2915003492159	3.19794
GBT	6680008744609	3.23416
LGA	1680007588152	3.23635
GAJ	6625010645906	3.24942
GBF	4320007257386AX	3.25049
GBX	6685009302771	3.26918
RED	2915005401801	3.32908
PEG	2990006028693	3.37048
PFK	2840000097603RW	3.38497
LAB	4920009274484DQ	3.39188
PCE	2840003266062PT	3.44895

Group 3--Continued

Manager Design.	Stock Number	Ratio
LBS	6680005511652	3.50700
PFM	2920004624848YP	3.51433
LT3	6350002963328	3.52447
GCF	1680010370329	3.53575
LGB	1680000754925	3.55529
GEJ	1680004400028EV	3.61268
GAE	6625000037074	3.62716
PCA	2995002819796PT	3.69163
REL	4820001066610FS	3.71430
GBN	6680009382155	3.72426
GCC	1680008098502	3.73903
GBN	6680009840301	3.74117
PEH	2915010097932	3.78892
GBD	6645000700320	3.82685
LAB	4920004902880	3.85660
REA	2915000843949	3.87261
GBN	6680003336743	3.94722*
PFK	2840008931321RW	3.99491
RFD	2915006263123RW	4.02909
GAV	4920009276532DQ	4.05592
GAY	4920000429568DQ	4.06979
GBE	4920004973098	4.09586
LGA	1680007029382LS	4.11718
GCE	1680009448371	4.16248
LB3	6680009533234	4.16606
LBN	6680005312988	4.21752
REA	2915009667731	4.21990
PEC	2915009719131	4.23315
GFM	4810007133144	4.23474

Group 3--Continued

Manager Design.	Stock Number	Ratio
LA2	4920001098374DQ	4.36827
GBN	6680001957338	4.54258
GCG	1680006775227	4.56433
GFA	1680009797782LS	4.57047
GAV	4920004600339DQ	4.59266
GEJ	6605001791529EV	4.63234
GBU	6685010208749	4.64837
GAJ	6625003903851	4.65815
GBF	4310001249688AX	4.66877
GAJ	6625001379077	4.71508
RFA	4320006740932RW	4.91666
LBY	6680005511651	5.12560
PCA	2925003276217PT	5.19919
GBE	4920007594706	5.42279
GAX	4920010389108DQ	5.47467
GAK	6625009117243	5.54036
GCQ	1680000736827	5.86401
GA4	4920010325317DQ	5.94852
GAN	6625004502020DQ	6.07698
GAJ	6625010582419	6.11392
GAQ	4920004444526DQ	6.24893
RFF	2915006164726RW	6.36923
GAK	6625009293951	6.39264
GAH	6625004444064	6.39464
GAH	6625005580059	6.41133
PCD	2840003479686PT	6.72126
PEA	2915000740432	7.01488
GAU	4920002283588DQ	7.05389
GAV	4920004973124DQ	7.16244

Group 3--Continued

Manager Design.	Stock Number	Ratio
PCX	2840003522148PT	7.40070
GAN	6625004224289DQ	7.52304
PED	2915008715870	7.61353
GAH	6625004223459	8.17923
PFD	4810005283666 RW	8.47558
PEL	2915000599582	9.35487
GAC	6625010199977	10.12420
GBH	4920010841588	10.73510
GAU	4920004023060DQ	12.49556
PCA	2995002952481PT	14.15163
PCA	2995005343027PT	16.51857
GAV	4920009236267DQ	36.24048
GAB	4920010328095DQ	43.90885
GBG	4920001245354	3606.55738
GAN	4920001122438DQ	6760.56338

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